Role of Climate, Rocks, and Soils on the Wines of Napa Valley, California

Part 2 of 2

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This article is the second and final part of an earlier article (Popkin, 2023). It presents more detailed geological and pedological information and the insights into the wines of Napa Valley gained therefrom.

Table 1 illustrates estimated hydraulic parameters of selected soil types. Hydraulic conductivity is a measure of a material's capacity to transmit water. It is expressed as the volume of water at the ambient kinematic viscosity that will move during a unit of time under a unit hydraulic gradient through a unit area measured at right angles to the direction of water flow. Porosity is a measure of voids or openings within a material. It is expressed as the ratio of the volume of openings to the total volume of the material. Specific yield is the ratio of the volume of water that will drain under gravity to the total volume of the saturated material. Specific retention is the ratio of the volume of water retained after gravity drainage to the volume of the saturated material.

Down Among the Bedrock at Napa

Simply put, parent materials or rocks and underlying bedrock, erode and weather under the influence of water, microorganisms, and time to produce soil. The parent materials are the source of the soil's fertility and also impact its drainage and nutrient availability. Where soils are thin or well drained loams and sands, the roots of grape plants will seek water and nutrients from the fractures underlying the soil, as discussed below in "Sounding out the soils."

To paraphrase Geetapetals (2021), the different types of rocks will fracture in different ways. Some rocks fracture more than others, making water and nutrients more available to aggressive roots. Limestone fractures well, dolomites less so. Natural wines from roots in limestone, as in the case of Burgundy grown on limestone, for example in Venezia Giulia, northeast Italy, tend to have more acidity and a "chalky nose." Dolomite Burgundy has less chalk. The Venezia Giulia is a typical limestone region in northeastern Italy. Foradori is a typical dolomite high-altitude wine from this region.

French and German wines tend to be grown on calcareous soils derived from limestone and dolomite.

Young, undeformed granite is dense and not very fractured. Older, deformed, fractured, and weathered granites produce sandy regolith which yields high acidity and tannin experienced at the front of the mouth and on the lips. Such wines are produced in the Bolo region in northwestern Spain and north Portugal, in South Africa and the Northern Rhone valley.

Basalt tends to produce wines that aren't very tannic (dry, bitter, or astringent-like), with a marked acidity on the sides of the mouth. These wines may be perceived as tasting peppery. They are common in the U.S. west coast of Washington, Oregon, and California. Chilean wines tend to be a mixture of granitic and basaltic based.

Table 1. Estimated values of hydraulic conductivity, porosity, specific yield, and specific retention in selected soils. From Heath (2004).

Soil Type	Hydraulic Conductivity, ft/day	Porosity, % by volume	Specific yield, % by volume	Specific retention, % by volume
Loam	0.0000008-0.0008	55	40	15
Clay	0.002-10	50	2	48
Silt, loess	0.2-80	25-55	22-40	15-48
Silty sand	1-1,000	25-55	22-40	15-48
Fine to coarse clean sand		25	22-40	3-15
Sand		25	22	3
Gravel	2,000-15,000	20	19	1

Schist tends to produce wines with noticeable acidity in the upper back of the jaw, somewhat like a dentist drilling. There's also moderate tanning on the sides and front of the mouth. Such wines include Cote-Rotie Region of the northern tip of France's Rhône Valley, Riberia-Sacra from the Spanish Denominación de Origen Protegida in the Galicia, and Anjou from the Loire Valley in France.

Gneiss wines can be somewhat between granite and basalt.

Slate bridges the gap between schist and limestone. The Mosel Region in Germany is a good example.

Of course, there are a great many more examples of rock types and trace elements directly influencing wine varieties.

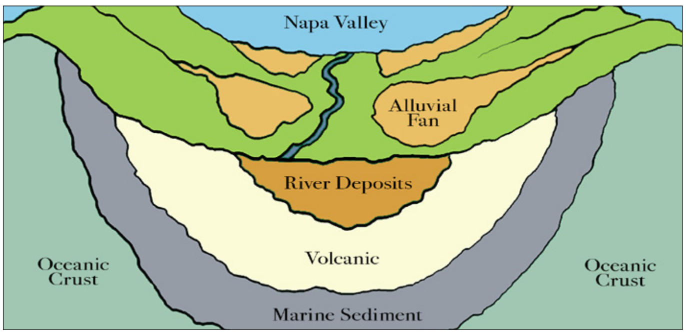

Figure 1. Schematic Geologic Panoramic of Napa Valley, California (Master Wine Tours, 2018).

Sounding out the Soils of Napa

Figure 1 is a schematic geologic panoramic of the Napa Valley, a world-renowned wine-production region in northern California. Note its inclusion of older oceanic crust beneath marine sediment, volcanics, and younger alluvial fans. The valley sits in a syncline of Cretaceous oceanic crustal rocks (the Franciscan) which was partially subducted beneath the Sierra Nevada (off the cross-section to the East) during the Oligocene. The Franciscan is overlain by the Great Valley sequence composed of land-derived synorogenic sediments and volcanic rocks derived from the Sierra Nevada.

As noted by Swinchatt (2002) and many others, the Napa Valley is "a rugged terrain of great variety in bedrock, soil and microclimate." This complexity and ruggedness have meant that the valley has been divided into 16 American Viticultural Areas so as to facilitate comparison of its many widely different wines.

To a large extent, it is the clay content of grape-producing soils that determines their drainage and fertility. According to Geetarpetals (2021), the topsoil layer is largely important for water retention and initial nutrient supply. More clay means higher soil-water retention, a longer ripening period, and more "black fruit" or abundant nutrients for natural wines. Less clay means fewer nutrients for the grapes, less time in which to ripen and more "red fruit". If the top layer is nutrient rich with plenty of water, then the grape vine can have small, short roots and will not struggle for water. It can make a bland juice, and not work hard to achieve its biological end goal of making sugar-rich grapes.

In well-drained loamy and sandy soils, the rock below the topsoil becomes more important. This is especially true for old-vine vineyards in the top classical wine producing regions. Poor nutrient and water content in the topsoil means the vines have to burrow deeply downward, seeking tiny rock fractures in their search for water and minerals. This is partially why limestone bedrock is favorable for good wines in poorly drained soils.

Wine grapes are generally associated with sandy soils on sedimentary rocks and soils on deep basalts. In Napa County, wine grapes are generally associated with Aiken, Bale, Clear Lake, Cole, Coombs, Cortina, Haire, Perkins, Pleasanton, Tehama, and Yolo soil series (Lambert and Kashiwagi, 1978). Well-drained and sloped-land soils generally require as much as twice the irrigation allotment as poorly drained and flat-land soils (see Table 2, columns 2 and 3). Since the 1970s, drip or trickle irrigation has replaced much sprinkler irrigation on sloped lands and sprinkler and row-flood irrigation on flat lands.

Wine-growing management practices include "suckering, pruning, turning winter cover crops under by disking, and controlling weeds by spring tooth and drag harrowing. Nematodes are controlled by fumigating the soil before planting. Sprinkler irrigation is used for planting, frost-protection, and heat-suppression. There is little or no response to fertilizers from fertilization. Sulfur-dusting controls mildew. Specific water management issues are noted below.

The irrigation unit "feet per acre" is commonly used in commercial farming and home gardening to describe the depth of applied water for a crop area to meet the specific crop's consumptive water demand for a specific soil type and condition, climate and water application method, Grape-suitable soils are classified by their irrigation water requirements as: Group 1, Early summer sprinkler irrigation at 0.5 feet/acre (ft/ac); Group 2, Tillage across slopes with early summer irrigation at 0.6 ft/ac; Group 3, Tillage across slopes with early summer sprinkler irrigation at 0.4 ft/ac; Group 4, Early summer sprinkler irrigation two or three times at 0.25 ft/ac; and Group 5, Tile drains or open ditches to keep the water table below the root zone, early summer irrigation at 0.6 ft/ac on loams and 0.3 ft/ac on clays. Well drained and sloped-land soils generally require as much as twice the irrigation allotment as poorly drained and flat-land soils. Since the 1970s, drip or tickle irrigation has replaced much of the otherwise sprinkler practices on sloped lands and sprinkler and row-flood irrigation on flat lands.

Soil texture, slope, and available water capacities define the grape-suitability groups as follows:

Grape-Suitability Soil Group	Description
Group 1: Pleasanton and Yolo	Group 1: Pleasanton and Yolo, Well-drained, moderate to slow vertical permeability, medium acid to neutral, thick loams on alluvial fans with less than 2% slopes and available water-holding capacities of 8-12 in. It has little or no erosion hazard, but occasional small-scale flooding.
Group 2: Pleasanton and Yolo well-drained	Group 2: Pleasanton and Yolo, Well-drained, moderate to slow permeability, medium acid to neutral, thick loams on alluvial fans and terraces with 2-5% slopes and available water capacities of 8-12 in. Soils are fertile, respond well to fertilizer, and are easy to till.

Grape-Suitability Soil Group	Description
Group 3: Perkins and Tehama	Group 3: Perkins and Tehama, Well-drained, slow permeability, slightly acid to mildly alkaline, thick gravelly loams or silt loams on alluvial fans and terraces with 0-9% slopes and available water capacities of 7.5-12 in.; Clear Lake, slow permeability, slightly acid to moderately alkaline, artificially drained clays on alluvial basins and valleys with 0-2% slopes and available water capacity of 8-10 in.; Coombs and Haire, moderately well drained and drained gravelly loam, moderate slow to very slow permeability, medium acidic to very acidic, loam or clay loam with 2-4% slopes and available water capacities of 3-10 in.; and Coombs and Haire, moderately slow to very slow permeability, moderately well drained or well drained, very strongly acidic to medium acidic. gravelly loam, loam or clay loam on old terraces and alluvial fans with 2-9% slopes and available water capacities of 3-10 in.
Group 4: Excessively drained Cortina	Group 4: Excessively drained Cortina, Rapid permeability, neutral to mildly alkaline, deposition prone and erodible and thick gravelly loam or very stony loam on alluvium with 0-5% slopes and available water capacities of 2-5 in. Requires light, frequent irrigation. Crops respond well to fertilizers. Tillage is limited by stones.
Group 5: Somewhat poorly drained Bale and Cole; and Clear Lake	Somewhat poorly drained Bale and Cole, moderate slow or moderate permeability, infrequently flooded, subject to sediment deposition, slightly acid to moderately alkaline, thick loam, silt loam, or clay loam with 0-5% slopes and available water capacities of 6-12 in.; and Clear Lake over-washed and high water-table, subject to sediment deposition, slow permeability, slightly acid to moderately alkaline, poorly drained clay with 0-2% slopes at low elevations in basins and valleys and available water capacities of 8-10 in.

There are 11 soil associations, or major groups of soil series, in Napa County, grouped according to their landscapes. Four soil associations are based on alluvial fans, flood plains, valleys, and terraces landscapes; and seven soil associations are based on upland landscapes. Generally, soils on alluvial fans, flood plains, valleys, and terraces are thicker, finer-grained with slower permeabilities and higher water-storage capacities than upland soil. These soils are loams to clays, formed in alluvium from sedimentary and igneous rocks.

The major wine-producing soil associations are in alluvial fans, flood plains, valleys, and terraces. They are: 1. The Bale-Cole Yolo, 2. Tehama, 3. Reyes-Clear Lake, and 4. Haire-Coombs. These associations cover about 16% of the county. However, other soils are capable of wine-grape production if properly managed.

The Bale-Cole-Yolo soil association covers about 6% of the county. It is nearly level to gentle sloping, well drained and somewhat poorly drained loams, silt loams, and clay loams on series is well drained to poorly drained, nearly level to moderately steep soils on flood plains, alluvial fans and terraces. Soils formed on deep deposits of alluvium are derived from basic igneous and rhyolite bedrock.

The Tehama soil association covers about 3% of the county. It is nearly level to gently sloping, well drained silt loams on flood plains and alluvial fans. Soils formed on deep deposits of alluvium are derived from sedimentary rock.

The Reyes-Clear Lake soil association covers about 4% of the county. It is nearly level, poorly drained silty clay loams and clays on tidal flats, in basins, and on basin rims. Soils formed on deep deposits of alluvium are derived from sedimentary and basic igneous rocks.

The Haire-Coombs soil association covers about 3% of the county. It is nearly level to moderately steep, moderately well to well drained gravelly loams, loams, and clay loams on terraces. Soils formed on deep deposits of alluvium are derived from sedimentary and igneous rocks.

The features of the 11 major Napa Valley vineyard soil series generally thought to be the best wine-grape production soils are summarized in Table 2 on page 67. Figure 2 illustrates Napa Valley wine-suitability areas. Over 90% of the Valley is suitable for commercial wine production.

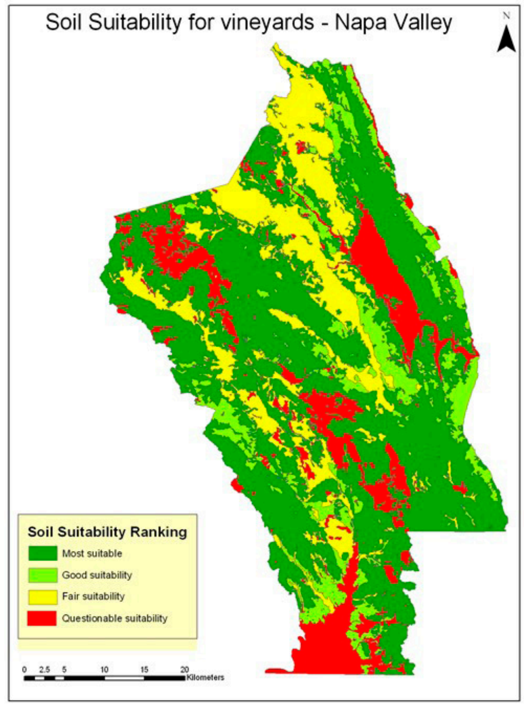

Figure 2. Napa Valley's Soil Suitability Ranking.
From: University of British Columbia, 2015.

Topography and Climate/ Weather and Wine Grapes in the Napa Valley

The Mercedes Effect – fog slips in "as smooth as a Mercedes changing gears" to naturally irrigate the Nape Valley vineyards (Skinner, 2003). Topography plays several roles, including accumulating fog and moisture in low-lying areas as well as eroded materials from nearby high-lying areas.

Conclusions

The grape, a product of biology and terroir, and yeast provide the sugar for the alcohol which makes wine, while the soil provides the nutrients and trace elements which makes the 1) visual (color and brilliance), 2) smell (aroma), 3) taste (and tannin), and 4) touch (body and mass), detected four human senses related to wine. The clink of wine glasses adds the fifth sense, sound.

Based on USGS Geologist Dr. David Howell's (1999, 2002) and Swinchatt and Howell (2004) breakthroughs in Napa Valley geologic analysis and his several recorded interviews of vintners (MacNeil, 2020) of diverse and conflicting wisdom

about 20 years ago, it appears that with sound master-vintner knowledge, resources, skills, and management, high-quality fine wines may be produced from otherwise paltry terrane.

Recommendations for Research

Ongoing research into wine-making at universities like the University of California at Davis, Cornell, Washington State, California Polytechnic, and Oregon State, foreign universities and research centers (especially in Australia, France, Italy, Spain, and Israel), culinary schools, and wineries themselves is long-ongoing and challenging. As in any agricultural crop research, much time is required for multi-variate field trials over several conditions to establish definitive results. Some interesting research areas include: hardy cropping patterns (seed variety selection), drought/ flood resistance, crop pest and disease control, potential for genetically modified organisms, improved soil fertility, soil amendments and nutrients, water quality and watering amounts and frequencies (water consumptive use), factor analysis of determinative parameters for pruning, harvest scheduling, grape processing and juice mixing, wine processing, monitoring and evaluation of important parameters for improved productivity and quality, and mapping and modeling appellative areas.

Table 2. Summary and description of features of major Napa Valley vineyard soil series

Vineyard Soil Series and Description	Drainage	Slope, %	Landscape and Elevation, ft	Permeability	Parent material	Water Capacity, in.
1. Aiken: thin acid loam	Well	2-50	Upland soil; 300-2,500	Moderate to slow	Basic volcanic rocks: basalt and andesite	6.5-11
2. Bale: thick acid loam	Poorly	0-5	Alluvial fans, flood plains and low terraces; 100-300	Moderate	Rhyolite and basalt	6-9
3. Clear Lake: thick clay or clay loam	Poorly	0-2	Old alluvial fans and basins; 20-250	Slow	Sedimentary rocks	8-10
4. Cole: silt loam	Poorly	0-5	Alluvial fans and flood plains; 100-300	Moderate, slow	Alluvium from sandstone, shale, and basic rock	10-12
5. Coombs: thick, acid gravelly loam & clay loam	Well	0-5	Terraces; 100-500	Moderate slow	Mixed alluvium from igneous and sedimentary rocks	6-10
6. Cortina: thick gravelly loam	Excessively well-drained	0-5	Flood plains and alluvial fans; 100-500	Rapid	Recent stratified alluvium	
7. Haire: acid loam	Moderately well	0-30	Old terraces and alluvial fans; 20-300	Very slow	Alluvium from sedimentary rocks	
8. Perkins: acid gravelly loam	Well	2-9	Terraces; 150-1,500	Slow	Alluvium from igneous rocks	7.5-8.5
9. Pleasanton: acid loam	Well	0-5	Alluvial fans; 50-600	Moderately slow	Alluvium from sedimentary rocks	8-9
10. Tehama: acidic silty loam	Well	0-5	Alluvial fans and terraces	Slow	Alluvium from sandstone and shale	10-12
11. Yolo: thick, neutral loam and silt loam	Well	0-5	Alluvial fans	Moderate	Recent alluvium	0-12

Adapted from Carpenter and Cosby, 1938; Lambert and Kashiwagi, 1978.

Examples of possible research topics are:

- Optimizing irrigation scheduling and water quality for well-drained and poorly drained soils
- Appropriate addition of soil nutrients like nitrogen, phosphorus, potassium, and trace elements and amendments like sulfur and gypsum to calcareous and alkaline soils, as well as lime and alum to acidic soils
- Best grape harvesting scheduling and wine making and aging procedures
- Best integrated crop and pest management strategies
- Most important factors to focus on for best quality and yields

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